Onset of arterial ‘steal’ following proximal angioaccess: immediate and delayed types

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Abstract

Background. Critical hand ischaemia following angioaccess is a potentially devastating complication and timely surgical repair is necessary to prevent permanent sequelae. However, the duration of the post-operative surveillance needed to exclude its occurrence has not been determined.

Methods. A retrospective review conducted over a 10-year period revealed 28 patients with critical hand ischaemia following access and surgical repair. The initial access that resulted in the limb-threatening ‘steal’ included 10 autologous brachiocephalic arteriovenous (AV) fistulae and 18 AV bridge grafts. The two groups of patients, those with autologous AV fistulae and those with AV bridge grafts, were compared regarding the time elapsed from the initial access to the correction procedure, the systolic pressure index between the two forearms and the existence of tissue loss.

Results. There was a highly significant difference in the time elapsed from the creation of the initial access to the revision procedure among the two groups, the median time being 2 days in the AV graft group and 165 days in the autologous group (P < 0.00001). The method of treatment was the distal revascularization-interval ligation (DRIL) procedure in the majority of patients (23 of 28), with immediate relief of ischaemic symptoms in all and a mid-term 1 year patency of 69%.

Conclusions. Severe steal develops immediately following AV bridge grafting and patients should be closely monitored during the first 24 h; surveillance is not indicated beyond 1 month. In contrast, steal following formation of proximal autogenous fistulae may be either of immediate or of ‘late’ onset, months or years after the creation of the fistulae, and lifelong monthly surveillance is recommended. Close monitoring is also recommended after any subsequent surgical or interventional correcting procedure for all access types. DRIL is the procedure of choice in limb-threatening severe steal.

Keywords: arteriovenous fistula; arteriovenous graft; haemodialysis; steal syndrome

Introduction

Hand ischaemia following angioaccess is a potentially devastating complication. If severe and left untreated it can lead to irreversible neurological dysfunction or digital gangrene; timely repair by surgical means is necessary to prevent permanent sequelae. Clinically significant distal extremity ischaemia occurs in 1.6–8% of all individuals with a functioning access. Predisposing risk factors include female sex, age > 60 years, diabetes, multiple previous access procedures on the same arm and the use of the brachial artery as the donor vessel [1]. It is impossible to predict pre-operatively which patients are going to develop this complication and the duration of the post-operative surveillance needed to exclude its occurrence has not been determined.

The aim of this 10-year study was to review all cases of severe arterial ‘steal’ following proximal angioaccess creation and to determine the time from the initial surgical procedure to the onset of symptoms.

Subjects and methods

The medical records of all patients presenting with limb-threatening arterial ‘steal’ following any proximal upper
extremity access procedure and necessitating any type of surgical correction in a 10 year period (1993–2002) were examined. ‘Proximal’ was considered any access procedure having the brachial artery as the donor artery. The definition of limb-threatening ischaemia was based mainly on clinical grounds, including rest pain, drop hand or any motor impairment and prolonged impaired sensation with simultaneous systolic pressure indices <0.5. This retrospective review revealed that 28 patients with critical hand ischaemia following access surgery required surgical revision during the study period. The total number of proximal access procedures performed in that period was 569 [176 brachiocephalic arteriovenous (AV) fistulae, 343 AV bridge grafts and 50 basilic transpositions]. As four patients were referrals, the estimated incidence of limb-threatening steal following proximal access procedures was 4.2%. The initial procedures resulting in limb-threatening ‘steal’ included 10 autologous brachiophalic AV fistulae and 18 AV bridge grafts (17 straight arm PTFE grafts and one loop forearm PTFE graft). The incidence following AV bridge grafts was 5.2% and that following brachiophalic AV fistulae 3.4%. Recognized risk factors for the development of steal syndrome, including age, female sex and diabetes, were recorded. The time elapsed from the initial access to the correction procedure (days), the systolic pressure index (SPI: systolic forearm pressure in the index arm distal to the access divided by the contralateral arm systolic pressure) and the existence of tissue loss were also recorded. No angiography was performed in any of the patients. The two groups of patients, those with autologous AV fistulae (n=10) and those with AV bridge grafts as initial access (n=18) were compared regarding the recorded variables. Statistical significance for categorical variables (sex, diabetes, tissue loss) was assessed by $\chi^2$ test or Fisher’s exact test, when appropriate. Numerical variables (age, SPI, time interval from initial access) were evaluated by Student’s t-test or its non-parametric equivalent, the Mann–Whitney U-test, when appropriate. Mean values were used for normally distributed variables, otherwise median values were employed. Life-table analysis was used to assess the cumulative patency of the revised access procedures. Data were analysed using the statistical package Statistica, with differences considered significant at the level of $P < 0.05$.

Results

Indications for surgical treatment were rest pain and/or drop hand in 22 patients and gangrene in six. Interestingly, all but one of the cases presenting with tissue loss were in the autologous group. Sixty-two per cent of the patients were diabetic (18/28), however, no peripheral arterial obstructive disease (PAOD) of the upper arm was pre-operatively diagnosed. Pre-operative exclusion of PAOD was based on clinical examination and bilateral brachial blood pressure measurements when difference was <20 mmHg. The mean pre-revision SPI value (data available for 24 patients) was lower in the AV graft group, but the difference did not reach statistical significance. There was a significant difference in the time elapsed from the creation of the initial access to the revision procedure among the two groups, the median time being 2 days in the AV graft group and 165 days in the autologous group (Table 1). The method of treatment was the distal revascularization-interval ligation (DRIL) procedure according to Schanzer et al. [2] in 17 and elongation of the graft with transposition of the arterial anastomosis distally in the radial artery in one patient in those having AV graft initially. In the autologous AV fistulae group, three patients had been treated by ligation of the fistula, six by DRIL and one by elongation-transposition of the cephalic vein distally and creation of a new anastomosis in the radial artery. The revascularization in the DRIL procedure was achieved with the saphenous vein in 20 cases, with a PTFE graft in three and in all cases the distal anastomosis was performed in the distal brachial artery. All patients treated by DRIL showed immediate significant or complete symptomatic improvement. Despite successful surgical correction of steal, extended tissue loss required finger amputation in three patients. Of the 23 initial access procedures that required DRIL, six thrombosed during the study period (all AV grafts), resulting in a symptom-free cumulative patency of 69% and 54% at 1 and 2 years, respectively. In two patients, the distal bypass (saphenous vein in both cases) was also thrombosed at 2 and 6 months, respectively, leading to finger gangrene and amputation in one.

Discussion

Clinically significant hand ischaemia occurs in 1.6–8% of all proximal upper extremity accesses [1].

### Table 1. Descriptive data on 28 patients who underwent surgical repair of arterial steal following upper limb proximal access

<table>
<thead>
<tr>
<th></th>
<th>AV bridge grafts (n=18)</th>
<th>AV fistulae (n=10)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years: mean ± 1 SD)</td>
<td>67.8 ± 9.2</td>
<td>64.1 ± 4.3</td>
<td>$P = 0.2$</td>
</tr>
<tr>
<td>Diabetes</td>
<td>10</td>
<td>8</td>
<td>$P = 0.2$</td>
</tr>
<tr>
<td>Female sex</td>
<td>17</td>
<td>6</td>
<td>$P = 0.041$</td>
</tr>
<tr>
<td>Time interval from initial access (days) [median (range)]</td>
<td>2 (1–30)</td>
<td>165 (60–720)</td>
<td>$P = 0.00001$</td>
</tr>
<tr>
<td>SPI (mean ± 1 SD) [median (range)]</td>
<td>0.24 ± 0.15</td>
<td>0.36 ± 0.11</td>
<td>$P = 0.09$</td>
</tr>
<tr>
<td>Tissue loss</td>
<td>1 (5%)</td>
<td>5 (50%)</td>
<td>$P = 0.012$</td>
</tr>
</tbody>
</table>
Its natural history was evaluated in a previous publication and in the majority of those having mild symptoms acutely after the establishment of an access, the SPI improves over the following months and symptoms resolve without intervention [3]. The majority of patients in these series had more than one of the known risk factors, including diabetes, female sex and age > 60 years, however, the higher incidence of steal following autologous fistulae reported previously was not confirmed [1]. Surgical repair is reserved only for those with severe limb-threatening ischaemia. Pre-operative angiography was not performed in these series and there is controversy about its routine use before embarking on surgical revision of steal [3]. Selective arteriography of the donor artery may be helpful in the 20–30% of patients who have proximal inflow stenosis. In those cases, compression of the AV fistula is an additional manoeuvre to visualize the impaired distal peripheral vessels [1]. Pre-operative duplex evaluation is also not sufficient to establish the diagnosis. Retrograde flow in the brachial artery just distal to the fistula is detected in the majority of patients following proximal access creation, indicating that the access consumes not only the antegrade flow, but also a portion of the collateral flow to the forearm [1–3]. However, pre-operative duplex should be useful in ruling out other causes of ischaemia, such as distal arterial occlusion due to technical error at the anastomosis, distal propagating thrombus, etc. The diagnosis is based mainly on clinical grounds supplemented by SPI measurements. Among the various options for the surgical treatment of steal, the DRIL procedure seems to be the more attractive. DRIL includes arterial ligation placed just distal to the takeoff of the AV graft or anastomosis and short bypass from a point 4–5 cm proximal to the inflow of the access to a point just distal to the ligation [2]. Haimov et al. [4] reported cumulative patencies 73% and 45% at 1 and 2 years, respectively, while Knox et al. [5] recently reported patencies of 83% at 1 year and 71% at 3 years. The reported DRIL patency of 69% at 1 year in our series confirms the good mid-term results of this technique. Alternative methods of repair include ligation of the access, elongation of the graft with transposition of the arterial anastomosis in a distal artery and various banding techniques. The problem in banding techniques or in using a 4–7 mm tapered graft is based in the difficulty in establishing the degree of stenosis required for sufficient reduction in flow while maintaining the patency of the access. Reported patencies at 1 year by Odland et al. [6] and DeCaprio et al. [7] following banding were 38% and 9%, respectively, definitely inferior of those following DRIL. Two recent articles, however, report intra-operative use of duplex ultrasound scan to achieve optimal flow reduction during the surgical repair of steal, with good results in four patients [8,9]. Flow reduction by banding may be an option in high-flow accesses (>1500 ml/min), however, high flow is a factor predisposing rather to chronic heart failure than to distal ischaemia. The use of a 4–7 mm tapered graft does not protect from steal and in a recent trial its routine use is not indicated [10]. The elongation technique also increases the resistance of the outflow by the interposition of extra length of either graft or vein [11] and has the same difficulties as banding. Access ligation is the simplest method of treating steal, but it has the obvious drawback that a valued access site is lost.

Flow in prosthetic bridge grafts tends to reach its maximum early after creation and thereafter decreases in a variable but progressive fashion [12]. In accordance with this, the vast majority of limb-threatening ‘steal’ symptoms occur immediately after construction of the access in series, including mostly AV grafts [4,6,13]. Wixon et al. [14] first discriminated that the development of steal may be either early (<30 days) or late (>30 days), but they didn’t mention any relation of the type of onset with a particular access category. It has also been observed that symptoms that occur acutely are often self-limiting and resolve with observation [3]. In contrast, symptoms with late onset, usually after the first month, are frequently progressive and tend not to resolve with conservative treatment. We observed that the ‘late onset’ pattern of access-induced steal is related almost exclusively to proximal autologous AV fistulae, while the ‘early onset’ type is associated with AV grafts. In our series, a highly significant statistical difference was noticed regarding the time elapsed from the initial access creation until the repair between the autologous and the AV graft group (Table 1). A similar observation was made in a small series of six access-induced steal cases: in four cases following AV grafts symptoms appeared immediately after operation, while in two autologous fistulas the onset was delayed 3 weeks and 7 months, respectively [15]. An explanation is that in contrast to AV grafts where flow tends to reach its maximum early after creation and thereafter decreases progressively due to a gradually developed outflow stenosis, fistula flow may gradually increase over time as the venous outflow dilates.

Contrary to the observations of the present study, some authors reported late onset of steal in AV grafts and early onset in autologous fistulae [11,16]. A possible explanation is that there are three different clinical mechanisms in which significant steal occurs: (i) steal that occurs only on haemodialysis as a result of a decrease in systemic arterial pressure, (ii) steal caused by an inflow stenosis and (iii) steal resulting from discordant fistula/peripheral vascular resistance [1]. It is obvious that our findings regarding the relation of onset of steal with the access type are applicable only in the third scenario, which is the most common form of ischaemic steal syndrome. There is no mechanism justifying late onset of steal in AV bridge grafts, however, delayed steal may develop after revision of the venous outflow tract [6,13,17]. Sporadic exceptions to this situation may be a result of progressive atherosclerosis not linked to the access,
as Yeager et al. [18] observed that finger gangrene in haemodialysed patients is often the result of atherosclerosis and was unrelated to a functional AV fistula in 52% of cases.

In conclusion, severe access-related steal develops immediately following AV bridge grafts. Patients should be closely monitored during the first 24 h and post-operative surveillance for steal is not indicated beyond 1 month, except for those with SPI < 0.5 [3,19]. In contrast, steal following proximal autologous fistulae may be either of immediate or of ‘late’ onset, several months or even years after the creation of the access. The immediate type of steal is rare as the initial flow of the native fistulae is inferior to those of AV grafts. The delayed type is predominant and when misdiagnosed and untreated leads more often to finger gangrene. Lifelong monthly clinical surveillance and SPI measurement, when appropriate, is recommended for proximal autologous fistulae. Close monitoring for steal is also recommended immediately after any subsequent surgical or interventional correcting procedure, either for grafts or fistulae. The DRIL procedure should be employed in every case necessitating surgical repair, providing not only relief of symptoms but maintaining an acceptable mid-term access patency and is, in our view, the procedure of choice in access-related steal.

Conflict of interest statement. None declared.

References


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